Optimization of Grid Spacing in a Groundwater Model

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Abstract

A groundwater model needs to discretize the model grid with suitable spacing so that it can achieve the modeling goal and maintain the numerical stability required for the solution to converge. The grid spacing also needs to conform to the modeled domain and meet the proper size so that it can produce the suitable error for the model. Not only above mentioned is satisfied for a ground modeling, but also it is needed to concern on the intrinsic error that is depended on the available data, involved uncertainties and grid spacing. The paper only demonstrates how to practically optimize the proper grid spacing in a groundwater model for Mae Sai aquifers basin based on all above concerns. The optimized result turns out the proper grid spacing of FD of Mae Sai aquifers basin is 400x400 m^2.

Keywords: Optimization of Grid Spacing, Groundwater Model, Mae Sai Aquifer System

1. Introduction

An initial problem to develop a groundwater model is how large the grid spacing proper is. Most of commercial graphic user interfaces of ground model offer an automatic grid smoothing module or a modeler arbitrarily specifies grid size. However, this automatic grid smoothing module is able merely to discover the grid spacing that can satisfy the stability and fitting with the study domain. However, the automatic grid smoothing module cannot show the proper grid spacing on the view of error that is relied on the available data and uncertainties. Therefore each groundwater model will provide differently proper grid spacing due to having differently available data and uncertainties. This paper will firstly show how to practically optimize the grid spacing of a real groundwater model concerned on the error for a real case study of Mae Sai aquifers basin.

2. The Study Area and conceptual Model of Mae Sai Aquifers Basin

2.1 The study area

Mae Sai Basin is located in the Mae Sai-, Chiang San- and Mae Jan district which is the northernmost district of Chiangrai in the northern Thailand. Hills present in the westernmost part of the basin. The northern basin is flat area, while the high terrace areas where the natural recharge exists presents in the southeast and west of basin. The basin's altitude varies from +140 to +1450 m. (MSL) (Figure 1). The geological investigation of Department of Groundwater Resources (DGR, 2009) discloses that Mae Sai basin comprises of 4 aquifer layers which are intervened by 4 thin aquitard layers (Figure 2).

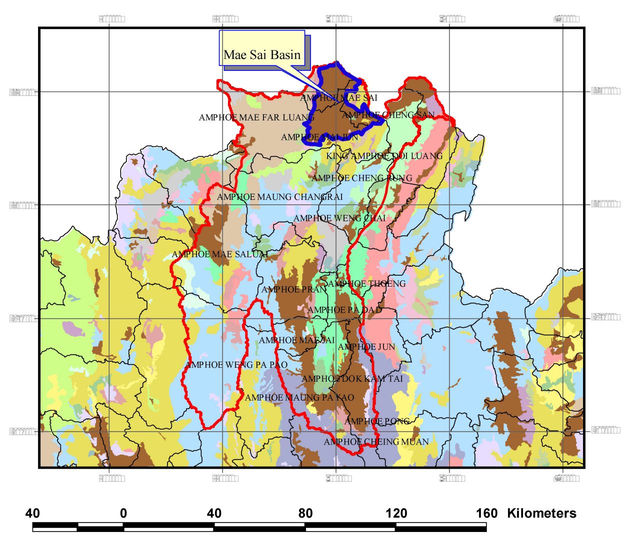


Figure 1. The Hydrogeological map of Mae Sai basin

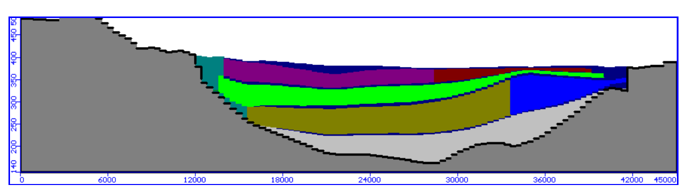


Figure 2. A cross-section of Mae Sai multilayered aquifers system

2.2 Conceptual Model of Mae Sai Aquifers Basin

As earlier mentioned in the section of study area, the Mae Sai conceptual model (Figure 3) is conceptualized into 8 modeled layers, namely, one top unconfined aquifer and 7 confined aquifers. The high altitude ridges of mountains in the west and east is specified as No Flow Boundary, while the flat area in North that is closed to the union of Myanmar is specified as General Head Boundary. The basin flanks that are the high terraces in West and Southeastern part of study area are specified as Recharge Boundary. The areas of Mae Kam and Khong river are specified as River Boundary (Figure 4).

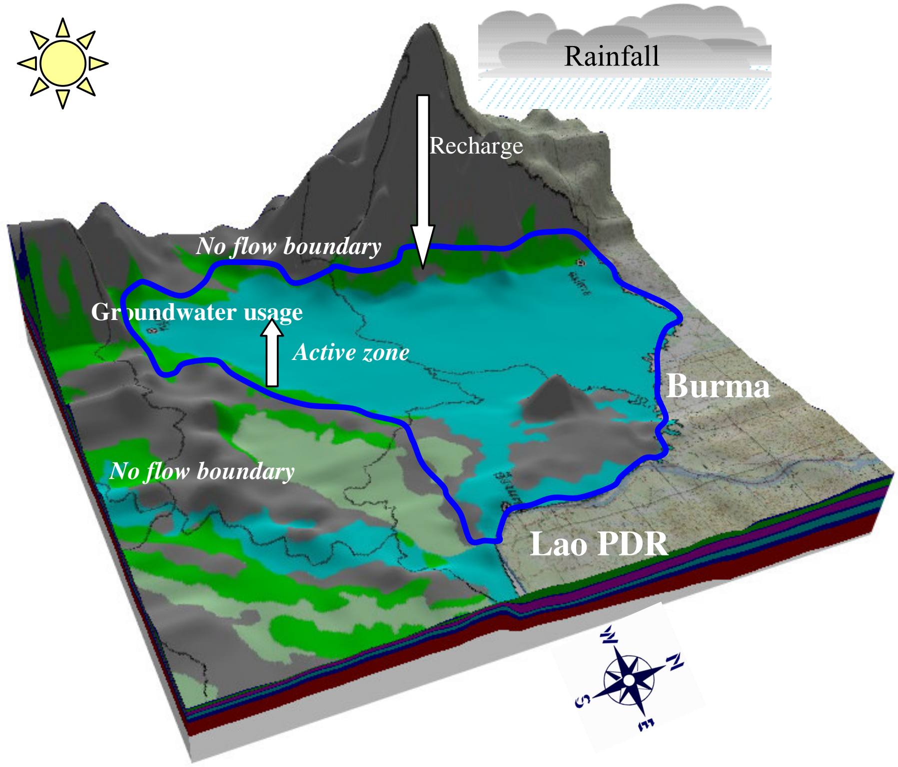


Figure 3. The conceptual model of Mae Sai aquifers basin.

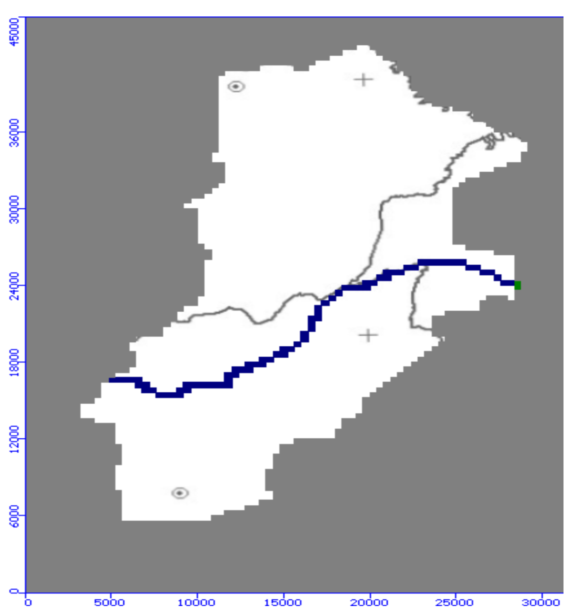


Figure 4. The Mae Kam river line at the top layer of Mae Sai groundwater model

3. Grid Design and Spacing

Generally, grid design is set up as follows (a) model grids are discretized following with the continuous natural system into segments (i.e., cells, elements and blocks) that permit numerical solutions to be computed, (b) the grid should be overlaid on a map of the area to be simulated. Grid boundaries should be located conforming to the conceptual model and following the guidelines discussed in the boundary condition section (Anderson and Woessner, 1992) and (c) in finite difference modeling, grid nodes lying outside the boundary are often designated as inactive cells to minimize computation volume.

Meanwhile, the grid spacing is conventionally designed to follows with the below criterions (US Army Corp, 1999): (a) the spacing between grids or so called "grid resolution", should be conformable to sharp changes in physical features, temporal conditions, and, numerical stability and overall model size constraints, (b) in three-dimensional models, model layers allow for the simulation of flow in separate hydrographic units, leakage between aquifers, and vertical flow gradients; typically, a model layer is selected for each hydrostratigraphic unit, however, if there are significant vertical head gradients, two or more layers should be used to represent a single hydrostratigraphic unit (Anderson and Woessner 1992), (c) the numerical error and unintended biases in solution of the flow equations can be minimized by avoiding large variations in node spacing and large aspect ratios which is the maximum dimension of a block or element divided by the minimum dimension and usually ideal for minimizing numerical errors: as a rule of thumb, aspect ratios up to 10:1 in non-sensitive areas of a grid are usually acceptable and expanding block or element sizes by 1.5 times the adjacent block sizes should be avoided and (d) the overall size of the grid should be sufficient to define the aquifer storage (pumping tests, geophysical methods), problem and produce results consistent with modeling objectives, but not so large as to cause excessive run preparation, computation requirements and an excessively large grid will expand the time requirements for each iteration, resulting in a cumulatively large impact to the modeling quality or schedule.

4. Optimize Grid Spacing

The previous section draws common criterions of grid spacing. However, as the uncertainty aspect which is mentioned in the introduction and the question of how large the proper grid spacing is cannot yet be overcame by using these criterions. Therefore the optimization of grid spacing is pursued to explore the intrinsic error which is only contributed from the grid spacing. Its result is expected to provide the proper grid spacing that gives the minimum error due to the grid spacing. The 3D of FD of Mae Sai groundwater model is induced to optimize its grid spacing. The fundamental idea of optimized grid spacing is to vary different sizes of grid spacing and then let the groundwater model run and check the measure of error between computed- and observed head due to that grid spacing. The observed head is collected from the spatial distribution of observed wells in the Mae Sai by DGR as shown in Figure 5. The root mean square error (RMS) is used for the measure of error in this paper. The next, the error measure is plotted against its grid spacing. From this plot, it will disclose the optimized grid spacing of this model. The grid spacing of Mae Sai groundwater model is varied with different sizes (Figure 6) and the groundwater model is run with different grid spacings. Then the misfit error versus grid spacing is drawn (Figure 7).

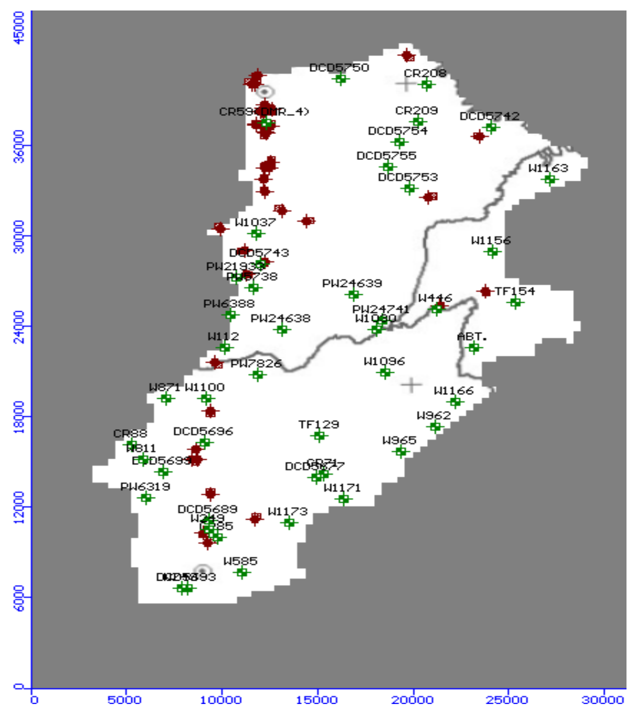
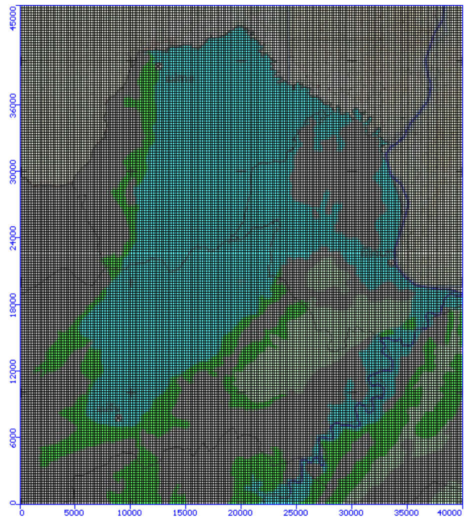
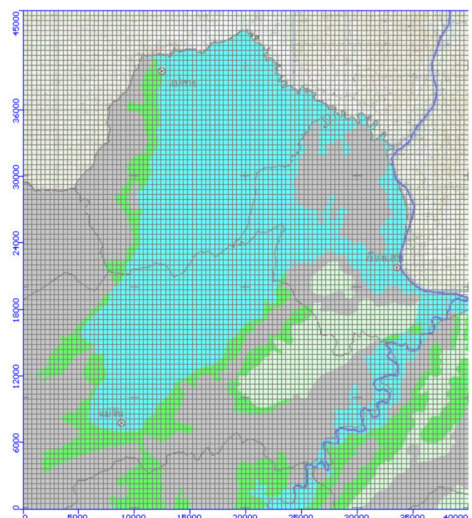


Figure 5. The locations of monitoring wells and pumping wells



(a) 225x225 m^2



(b) 400x400 m^2

Figure 6. Examples of different grid spacing of Mae Sai groundwater model

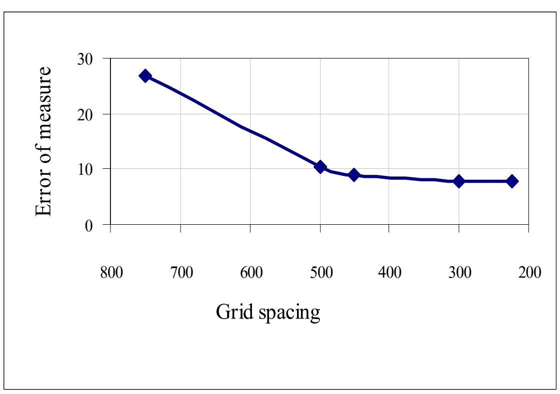


Figure 7. The grid spacing (m^2) versus error of measure (m)

The plot of grid spacing versus error unveils that the grid spacing of 400x400 m^2 is the proper grid size for the Mae Sai groundwater model, as it is the first grid spacing which starts to give the lowest error. Then this grid spacing is checked with the general criterions of grid spacing in the section 3 as follows: (a) the grid spacing is specified uniform grid spacing, as the most area of active cells are flat area, (b) the modeled layer is vertically discretized according to different hydrostratigraphic units, (c) its aspect ratio is lower than 10:1 and no any expanding grid spacing sizes by 1.5 times the adjacent grid spacing and (d) the overall size of the grid is sufficient to define the aquifer storage, as it can represent the different hydrogeological units. Furthermore the volumetric of groundwater model turns out the percent of discrepancy equal to zero. This shows that the grid spacing also the numerical stability of the model. The last the time consuming for a groundwater modeling run in the different grid sizes do not make any significant difference, as the current computer performance is very high powerful, therefore optimized grid spacing can disregard on the aspect of the time consuming for the different grid sizes. Therefore it can be concluded that the grid spacing of 400x400 m^2 of Mae Sai groundwater model can be met the general criterions and minimum uncertainty due to grid spacing by optimizing grid spacing.

5. Conclusion

The practical method of optimized grid spacing is applied with 3D of FD of Mae Sai aquifer model. It result shows the proper grid size of 400x400 m^2 of Mae Sai aquifer model can achieve the general concerns of grid spacing design and meet the minimum intrinsic error because of the grid spacing.

Acknowledgments

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Book

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